Homework #2

Conceptual Design and Options Considered with Budget and Timeline

Wireless Energy Transfer Group

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Introduction

The goal of our design project is to make electronic devices *truly* wireless by eliminating the need for wired power transmission. We intend to build a system consisting of two modules - a transmitter attached to a power source and a receiver that interfaces with an electronic device. The transmitter will transfer energy to the receiver through the use of resonant inductive coupling. Together, these modules will form a product that is both patentable and marketable to a wide range of users.

Previous Work

In the early 1900s, Nikola Tesla experimented with methods for wireless energy transfer over long distances using large electric fields. Recently, due to the dramatic increase in the use of wireless electronic devices, researchers have revisited the areas Tesla pioneered. Some have focused on the use of directed sources such as lasers and microwaves to transmit power, while others have used near-field inductive coupling.

The use of inductive coupling in transmitting power over very short distances has been developing rapidly in recent years, with companies filing numerous patents and bringing a small number of products to market. Specifically, Fulton Innovation has filed over 220 patents related to their eCoupled technology, and in 2001, they released the eSpring^{TM} water purification system. However, this technology has a limited range of only a few inches.

In 2007 a team of researchers from Massachusetts Institute of Technology (MIT) successfully demonstrated mid-range wireless energy transfer using electromagnetic coupling by transmitting 60 watts of power with ~40% efficiency to a load over two meters away. They were able to increase transmission efficiency by coupling at resonance.

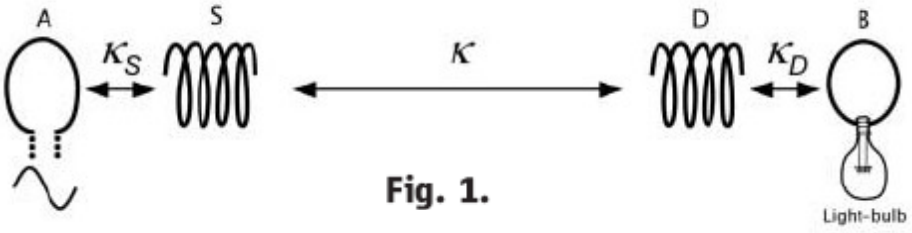

Fig. 1.

Figure 1 appeared in the research paper "Wireless Power Transfer via Strongly Coupled Magnetic Resonances," an article written by the MIT researchers. To take advantage of the market potential of their technology, deemed "Witricity," the MIT researchers formed a company by the same name.

eCoupled website - http://www.ecoupled.com/index.html

eCoupled patents - http://www.ecoupled.com/technologyPatents.html

"Wireless Power Transfer via Strongly Coupled Magnetic Resonances" - André Kurs, Aristeidis Karalis, Robert Moffatt, J. D. Joannopoulos, Peter Fisher, Marin Soljac ̆ic ́

"Wirelss Evanescent Coupling and its Connection to the Latest Developments Presented by Researchers at MIT" - Gerald DeJean

"Efficient wireless non-radiative mid-range energy transfer" - Aristeidis Karalis, J.D. Joannopoulos, and Marin Soljac ̆ic ́

Witricity website - http://www.witricity.com/

Witricity patent – Wireless non-radiative energy transfer, John D. Joannopoulos et al, U.S. Classification 333219000

Design Options

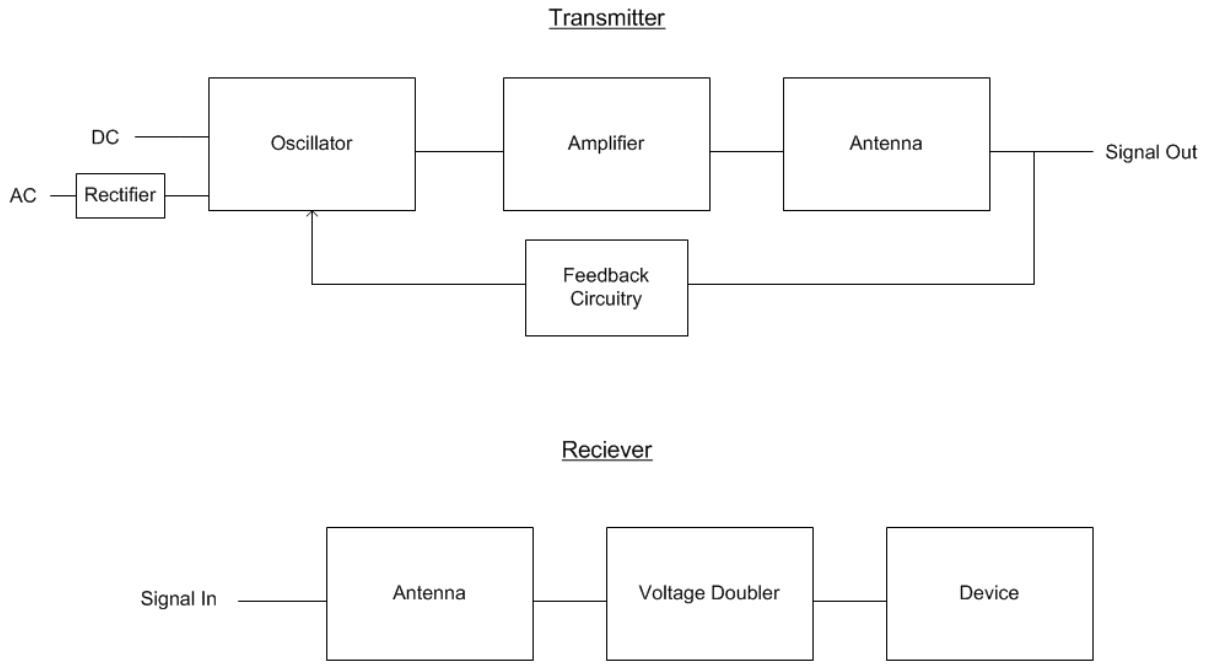

Figure 2: Functional Block Diagram of Our Design

Devices Considered:

Many devices were considered for the receiving end of our apparatus. These devices all have trade-offs we had to consider, such as power, range, cost, size, etc.

Wireless Mouse/Keyboard

Specifications for Mouse:

- Typically operate at ~3 V DC and ~100 mA
- Minimum dimensions: ~1.5" x 2.5" x 1.7", Maximum dimensions: ~3.5" x 6.5" x 2.4"
- Typical data transmitter to receiver distance: 1 – 10 ft.

Specifications for Keyboard:

- Typically operate at ~3V DC and ~50 mA
- Minimum dimensions: ~10" x 5" x 0.5", Maximum dimensions: ~24" x 8" x 2"
- Typical data transmitter to receiver distance: 1 – 10 ft.

Advantages:

- Low-power
- Close proximity to power transmitter
- Vertical orientation stays the same
- Inexpensive and large market

Disadvantages:

- Smaller volume for receiver
- Potential power transmission interference with computer data buses

Ceiling Fan

Specifications:

- Typically 120 volts and 50-90 Watts
- Enclosure dimensions: 12.3” diameter, 6” thick
- Typical transmitter to receiver distance: 8-10 ft. (with transmitter on or near floor)

Advantages:

- Can add ceiling fans and other amenities without extra wiring

Disadvantages:

- Requires large amount of power, which would require very large coils
- Efficiency is a major issue due to the 8-10ft distance

Heated Shoe Insole / Glove (Thanks, Dr.Schroeder!)

Advantages:

- Keep feet/hands warm during winter

Disadvantages:

- Must be thin enough to fit in shoe insole/glove lining
- Must be durable enough to walk on/handle items with
- Would require large range (many transmitters?)
- Orientation of devices would change with movement, causing flux problems

Game Controllers / TV Remotes

Specifications:

- Average Dimensions: 5” x 3” x 1”
- 5-15 feet from transmitter
- Max voltage requirements ~5V w/ low current, average on order of mA

Advantages:

- Low power
- No need to replace batteries
- Some charging can be done during use

Disadvantages:

- Somewhat long range
- Controllers will change orientations

Charge Laptop

Specifications:

- Approximately 18.5 Volts at 3.5 Amps
- Charges to a battery cell w/ active source switching (wall source vs. battery)

Advantages:

- No need for wired adapter
- Charging will commence at any time

Disadvantages:

- Requires high power
- Laptop would need to be fully recharged for optimum use, in other words one couldn't use the laptop and charge at the same time for a decent amount of time

After considering these devices for our implementation, we decided on the Wireless Mouse/Keyboard. Both of these devices do not change vertical orientation, are low power devices, and typically will have a close proximity to the transmitter. The other devices we considered often required too much power for reasonably sized coils to handle, or required the receiver to move frequently, which would upset the amount of power delivered or even prevent power from being delivered at all, due to the orientation of the receiving coil.

Method of Powering: USB, Wall Outlet, or Solar?

We considered three major methods of powering our transmitter. One method would be to draw power from a computer's power supply unit (PSU) via the USB port (outputs max of 5 V DC at 500 mA). Another method would be to draw power from a wall outlet (outputs max of 120 V AC). The third method involved harnessing solar power via the use of solar panels. This option is appealing because it would allow the user to acquire free, clean energy from the sun.

Method of Powering: USB

Advantages:

- Convenient for computer peripherals
- Virtually no safety hazard

Disadvantages:

- Not viable for high power applications
- Draws from PC's limited power supply
- Maximum output is 5V and 100mA

Method of Powering: Wall Outlet

Advantages:

- Good for high power applications
- No need for AC/DC conversion until device input

Disadvantages:

- More safety considerations
- Has accessibility/mobility issues due to fixed position at outlet
- Frequency would need to be increased from 60 Hz which would require conversion to DC adding extra components and cost

Method of Powering: Solar Panel

Advantages:

- Free energy
- Unlimited source
- Clean energy with an emerging market

Disadvantages:

- Expensive as a 30 W panel is ~$200
- Most charging applications require more than ~1.5 A; solar panels have low current output for the size
- Would need to store energy during the day for operation at night
- 30 W panels are about 2' x 1.5' in size which limits mobility

We decided on using a wall outlet to power our device, for several reasons. We ruled out solar power, because solar panels are expensive, have a large area for the amount of power they deliver, and have a low maximum output current. We then considered the remaining two options. We decided that we probably could not draw enough power from a USB port even for our low power applications, which did not make it a viable option. Wall outlet power will provide enough power and current for our device and circuitry, and it is the best option we have considered.

Number of Transmitters: Single or Multiple?

One of the design issues we had to consider was how many antenna/coil transmitters to have. Multiple transmitters would be placed around a room to provide a higher efficiency, and a single transmitter of the same type would have to be placed closer to the receiving unit with decreased efficiency.

Number of Transmitters: Single Transmitters

Advantages:

- Simpler design
- Eliminates chance of interference with other transmitters
- Less expensive cost

Disadvantages:

- Very small range of operation
- Efficiency limits device mobility

Number of Transmitters: Multiple Transmitters

Advantages:

- Extended range of operation

- Device can be incredibly mobile

Disadvantages:

- More complex
- More expensive
- More difficult to implement
- More energy will be lost than compared to a system with a single transmitter
- Multiple transmitters may interfere which each other, couple with each other, etc., which would require the need for more, complicated circuitry

After much deliberation, we decided to use a single transmitter for our implementation. Although multiple transmitters could possibly provide an extended range of operation, they would inevitably complicate the design to a great extent, and require many more considerations, such as the transmitters coupling and interfering with each other, as well as an increased cost, greater energy loss, etc. We feel that a single transmitter is the best option.

Budget

Part	Cost per unit	Quantity	Total Cost	Digikey Part#	Notes
IC PROG DELAY TIMER W/OSC	1.73	4.00	6.92	568-2886-5-ND 568-2887-5-ND	Oscillator for Signal Generation
Digital Potentiometer	1.61	12.00	19.32	Design Dependent	Input to Timer; Changes Freq of Signal Generator
20' 14 AWG Magnet Wire	4.74	4.00	18.96		Coil
PIC Processor	7.20	2.00	14.40	PIC16F876-20/SP-ND	Power monitoring, Adjusting frequency
Printed Circuit Board	50.00	2.00	100.00		Transmitter/Receiver PCBs
Miscellaneous Components	25.00	1.00	25.00		Resistors, Capacitors, Inductors, Etc.
Apparatus Enclosure(s)	60.00	1.00	60.00		Transmitter/Receiver Enclosures
Receiver Device/Load (Peripheral, Appliance, etc.)	100.00	1.00	100.00		Mouse, Keyboard, Fan, etc.
Research Materials (Books, IEEE documents)	60.00	1.00	60.00		
Total Cost			**404.60**		

Timeline

Gantt Chart Semester One		
Task	**Weeks**	**Who**
Requirements Capture	2,3	All
Options Considered	4,5	All
Budget	4,5	All
Timeline	4,5	All
Proof of Concept	5,6	All
Further Research	5,6,7,8,9	All
>>Antenna Design	5,6,7,8,9	Chris, Jeff
>>Signal Generator Design	5,6,7,8,9	Yash, Ross
Antenna Prototype Design and Test	7,8,9,10,11	All
>>Efficiency	7,8,9,10,11	Ross, Chris
>>Range	7,8,9,10,11	Ross, Chris
>>Effect of Extraneous Objects	7,8,9,10,11	Yash, Jeff
Design	9,10,11,12,13,14	All
>>Transmitter	9,10,11,12,13,14	All
>>>Oscillator	11,12,13,14	Yash, Chris
>>>Amplifier	11,12,13,14	Ross, Jeff
>>>Antenna	9,10,11,12,13,14	Yash, Ross
>>>Load Monitoring w/PIC	11,12,13,14	Chris, Ross
>>Receiver	9,10,11,12,13,14	All
>>>Antenna	9,10,11,12,13,14	Jeff, Chris
>>>Voltage Doubler	9,10,11,12,13,14	Yash, Jeff
>>>Device Interface	9,10,11,12,13,14	Ross, Chris
Order Parts	5,6,12	All
Create Multisim Schematics	12,13	All
Breadboard Circuits	13,14,15,16	All
Build Antennas	13,14,15,16	All
Test Breadboarded Circuits and Antennas	15,16	All
Prepare for Presentation	14,15,16	All
Gantt Chart Semester Two		
Continued Design	1,2,3,4	All
>Signal Generator	1,2,3,4	Yash, Ross, Jeff
>Amplifier	1,2,3,4	Chris, Jeff
>Load Monitoring w/ PIC	1,2,3,4	Ross, Chris, Yash
PCB Layout in Ultiboard	3,4,5,6	All
Build and Populate PCB	6,7,8	All
Test PCBs	8,9,10	All
Test with Device	10,11,12,13	All
Build Enclosure	11,12,13	All
Final Testing	12,13,14	All
Prepare for Presentation	13,14,15,16	All

Gantt Chart Semester One																
Task	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 12**	**Week 13**	**Week 14**	**Week 15**	**Week 16**
Requirements Capture		x	x													
Options Considered				x	x											
Budget				x	x											
Timeline				x	x											
Proof of Concept					x	x										
Further Research					x	x	x	x	x							
>>Antenna Design					x	x	x	x	x							
>>Signal Generator Design					x	x	x	x	x							
Antenna Prototype Design and Test							x	x	x	x	x					
>>Efficiency							x	x	x	x	x					
>>Range							x	x	x	x	x					
>>Effect of Extraneous Objects							x	x	x	x	x					
Design									x	x	x	x	x	x		
>>Transmitter									x	x	x	x	x	x		
>>>Oscillator											x	x	x	x		
>>>Amplifier											x	x	x	x		
>>>Antenna									x	x	x	x	x	x		
>>>Load Monitoring w/PIC											x	x	x	x		
>>Receiver									x	x	x	x	x	x		
>>>Antenna									x	x	x	x	x	x		
>>>Voltage Doubler									x	x	x	x	x	x		
>>>Device Interface									x	x	x	x	x	x		
Order Parts					x	x						x				
Create Multisim Schematics												x	x			
Breadboard Circuits													x	x	x	x
Build Antennas													x	x	x	x
Test Breadboarded Circuits and Antennas															x	x
Prepare for Presentation														x	x	x
Gantt Chart Semester Two																
Continued Design	x	x	x	x												
>Signal Generator	x	x	x	x												
>Amplifier	x	x	x	x												
>Load Monitoring w/ PIC	x	x	x	x												
PCB Layout in Ultiboard			x	x	x	x										
Build and Populate PCB						x	x	x								
Test PCBs								x	x	x	x					
Test with Device										x	x	x	x			
Build Enclosure											x	x	x			
Final Testing												x	x	x		
Prepare for Presentation													x	x	x	x

Summary

Our main objective is to implement a marketable and cost-effective truly wireless device using the properties of resonant evanescent wave coupling .We have decided by means of this document that the most appropriate implementation of our idea is a wireless mouse or keyboard implementation, drawing power from a wall outlet, by means of a single transmitter and receiver unit. The requested amount of funds for this project is $404.60. We believe that this is a reasonable and appropriate amount for our project, as indicated by our Budget chart. With the requested budget and our chosen implementation, this document has given us direction as to how to achieve our goal of Wireless Energy Transfer.